



**INTERFACE CONTROL DOCUMENT  
FOR THE TYPE E  
REACTION WHEEL ASSEMBLY**

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<b>Rev.</b>	<b>Description</b>	<b>Approval / Date</b>

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## **1.0 SCOPE**

This Interface Control Document (ICD) defines the electrical, structural, mechanical, and thermal interfaces between the Reaction Wheel Assembly (RWA) and the spacecraft. Also defined are all electrical connections that occur between the Reaction Wheel Electronics (RWE) and the Reaction Wheel (RW).

## **2.0 REFERENCE DOCUMENTS AND DEFINITIONS**

### **2.1 ITHACO Documents**

Outline Drawings	D44342 / D43758 (Appendix B)
External Wiring Diagram	D44346 (Appendix A)
Block Diagram	D44345

### **2.2 Definitions, Acronyms, and Abbreviations**

CW	Clockwise
CCW	Counter-Clockwise
EMI	Electro Magnetic Interference
EMC	Electro Magnetic Compatibility
ICD	Interface Control Document
RW	Reaction Wheel
RWA	Reaction Wheel Assembly
RWE	Reaction Wheel Electronics
TLMY	Telemetry

## 3.0 HARDWARE INTERFACE DEFINITION

### 3.1 Interconnect Definition

Included as Appendix A are interconnect diagrams that define the electrical connections between the spacecraft.

#### 3.1.1 Connector Description

The following is a list of all connectors on both the RW and RWE. Following each connector is a brief description of the connector's function.

##### Power Module

- 2A1J1: Test connector for the power module. This connector should be covered for flight.
- 2A1J2: Power input connector. This connector accepts power from the spacecraft.
- 2A1J3: Motor terminal connector. This connector interfaces with the reaction wheel 1A1J1 with a cable constructed as defined by the external wiring diagram on D44346, sheet 2.

##### Control Module

- 2A2J1: Command and Telemetry connector. This connector accepts torque commands and contains thermistor outputs as well as converter telemetry outputs.
- 2A2J2: Reaction wheel/control module card connector. This connector interfaces with the reaction wheel 1A1J2 with the cable constructed as defined by external wiring diagram D44346.
- 2A2J5: Test connector. This test connector should be covered for flight.

All connector pins are defined in the external wiring diagram D44346. Along with the connector pin definition are recommended cable configurations.

Connector types are defined on ITHACO drawing D44342, Outline, Reaction Wheel Electronics.

### 3.2 Electrical Interface Characteristics

#### 3.2.1 EMI Filter/Power Buss Interface

User power interface is to RWE connector 2A1J2.

The reaction wheel power interface is bi-directional in that the driver returns energy to the power bus during wheel drive down. The equations in this section show both the magnitude and direction of the power flow. For worst case power consumption, change converter power to 9.6 W and  $R_B$  to 0.65 .

### 3.2.1 EMI Filter/Power Buss Interface (Cont'd)

The following paragraphs describe a power profile for the Type E Reaction Wheel which includes all modes of operation - drive-up or drive-down at any commanded torque level. Input variables to the power profile include commanded motor torque, power bus voltage, and wheel speed. Output variables include total RWA power consumption as well as driver and wheel dissipations. Both worst case, end-of-life and nominal power data is provided.

Notes for use of the 4-quadrant power model - For accurate results, the 4-quadrant power model requires careful attention to variable polarities. The variables  $\tau$  and  $\omega$  must have polarities as defined below. The limits placed in  $\tau$  assume that the torque command input voltage is limited to  $\pm 5$  V.

Total Power Input:

$$P_{\text{INPUT}} \cong \frac{\tau_M^2}{k_T^2} R_B + \frac{|\tau_M| \cdot 1 \text{ V}}{k_T} + \frac{0.02|\tau_M| V_{\text{IN}}}{k_T} + 9.5 \text{ W} + \omega \tau_M \frac{k_E}{k_T}$$

$$+ \left( \frac{\tau_M^2}{k_T^2} R_B + \frac{|\tau_M|}{k_T} (1 \text{ V} + 0.02 V_{\text{IN}}) + 9.5 \text{ W} + \omega \tau_M \frac{k_E}{k_T} \right)^2 \frac{R_F}{V_{\text{IN}}^2}$$

where:  $\tau_M$  = commanded motor torque in N-m ( $-0.3 \text{ N-m} < \tau < 0.3 \text{ N-m}$ )

$\omega$  = rotor velocity in rpm;  $\omega > 0 \Rightarrow$  CCW rotation

$\omega < 0 \Rightarrow$  CW rotation

$$|\omega| = \frac{V_{\text{IN}} k_T - R_B \tau k_e / \sqrt{2}}{k_E k_T + \tau L_B / \sqrt{2}}$$

$\tau_D$  = drag torque at velocity  $\omega$ ;  $\text{sign}(\tau_D) = -\text{sign}(\omega)$   $\tau_D > 0$  when  $\omega < 0$   
Refer to drag torque plots for typical data

$\tau_R$  = Reaction torque on Flywheel in N-m;  $\tau_R = \tau_M + \tau_D$

$\tau_R > 0, \omega > 0 \Rightarrow$  Increase speed, CCW rotation

$\tau_R < 0, \omega < 0 \Rightarrow$  Increase speed CW rotation

$\tau_R > 0, \omega < 0 \Rightarrow$  Decrease speed CW rotation

$\tau_R < 0, \omega < 0 \Rightarrow$  Decrease speed CCW rotation

$V_{\text{IN}}$  = bus voltage at driver power connector in volts

$k_E$  = back-EMF constant = 0.0062 V/rpm

$k_T$  = motor torque constant = 0.062 N-m/A

$P$  = Input power in Watts;  $P < 0 \Rightarrow$  power returns to bus

$R_B$  = bridge resistance = 0.54

motor winding resistance = 0.33 @ 25°C (measured)

cable resistance (2 m) = 0.03 @ 25°C

MOSFET on resistance x 2 = 0.14 @ 25°C

magnetics, wiring resistances = 0.015 @ 25°C (estimate)

current sense resistor = 0.025

$L_B$  = bridge inductance = 0.000113 H-Hz/rpm

$R_F$  = EMI filter resistance = 0.1 @ 25°C

### 3.2.1 EMI Filter/Power Buss Interface (Cont'd)

Total Dissipation, Driver:

$$P_{\text{DRIVER}} = \frac{\tau_M^2}{k_T^2} (R_B - R_M - R_C) + \frac{|\tau_M| \cdot 1 \text{ V}}{k_T} + \frac{0.02 |\tau_M| V_{\text{IN}}}{k_T} + 8.9 \text{ W}$$

$$+ \left( \frac{\tau_M^2}{k_T^2} R_B + \frac{|\tau_M|}{k_T} (1 \text{ V} + 0.02 V_{\text{IN}}) + 9.5 \text{ W} + \omega \tau_M \frac{k_E}{k_T} \right)^2 \frac{R_F}{V_{\text{IN}}^2}$$

where:  $R_M$  = motor winding resistance = 0.33 @ 25°C  
 $R_C$  = cable roundtrip resistance = 30 m @ 25°C

Total Dissipation, Wheel:

$$P_{\text{WHEEL}} = 0.6 + R_M \frac{\tau_M^2}{k_T^2} + \omega |\tau_D| \frac{k_E}{k_T}$$

Total Work Performed:

$$P_{\text{MECH}} = \omega \tau \frac{k_E}{k_T}$$

Power Profile -  $\tau_D$  Summary

Nominal Drag (23°C)

0 to 500 rpm	$\tau_D = (0.010 + 0.00003 \omega) \text{ N-m}$
500 rpm up	$\tau_D = (0.020 + 0.000009 \omega) \text{ N-m}$

Cold (-10°C)

0 to 500 rpm	$\tau_D = (0.018 + 0.00003 \omega) \text{ N-m}$
500 rpm up	$\tau_D = (0.030 + 0.00001 \omega) \text{ N-m}$

Hot (50°C)

0 to 500 rpm	$\tau_D = (0.004 + 0.00003 \omega) \text{ N-m}$
500 rpm up	$\tau_D = (0.014 + 0.00006 \omega) \text{ N-m}$

#### 3.2.1.1 Inrush Limiter

The RWE, incorporates active inrush limiting. The EMI filter is precharged via a 4.22 resistor. This starts up the DC/DC converter which turns on the inrush limiter MOSFETS gradually. The maximum inrush current at a 35 V bus will be less than 10 A.

### 3.2.1.2 Outrush Limiting

Because of the bi-directional nature of the power interface, provisions must be made to deal with the situation where the power is disconnected during wheel drive-down.

The two diodes connected to unswitched power perform this function by clamping the driver's local power bus to 2 diode drops above the bus voltage. The RWE's DC/DC converter also contains an overvoltage shutdown which protects the driver from damage should the diodes become disconnected. This overvoltage shutdown is activated when the converter input voltage reaches 40–50 V.

### 3.2.1.3 Undervoltage Lockout

To protect the motor driver from abnormal power bus conditions, the RWE will not start unless the input power bus is at least 15 to 18 VDC. The RWE shuts down provided the input power bus is less than 12.75 V and the user is not commanding a wheel drive down.

## 3.2.2 Control Voltage Interface

The RWA receives an analog control voltage with the following characteristics:

1.  $\pm 10$  VDC Range
2. Positive voltage causes positive wheel rotation
3. Negative voltage causes negative wheel rotation

The Control Voltage input circuit is shown in the block diagram in Appendix C.

### 3.2.2.1 Direction of Rotation

Relative to the top cover (non-connector side) of the RW, a CCW torque will result on the flywheel when a positive torque command is applied. This will result in a CW reaction torque on the spacecraft. If started from zero rpm, the application of CCW motor torque will cause the flywheel to rotate in the CCW direction. The analog tach polarity is positive when the flywheel rotates in the CCW direction, and negative when the flywheel rotates in the CW direction.

### 3.2.3 Telemetry

The tachometer and current telemetry interface circuitry shown in the block diagram in Appendix C. The analog current telemetry is proportional to motor current. A telemetry is provided with an output voltage of 1/2 of the +5 VDC secondary voltage on the DC/DC converter. The interface circuit is shown in the block diagram in Appendix C.

Four thermistors are located in the reaction wheel and two thermistors are located in the MDE. Two of the thermistors in the reaction wheel are mounted on one side of the bearings, and two are mounted near the mounting surface. The two thermistors in the MDE are mounted on the DC/DC Converter Card near/adjacent to the wall. There will be a 5.1 k resistor in series with each thermistor to linearize the resistance/temperature curve of each thermistor, and to provide a bias current. The schematic in the block diagram is typical of each thermistor configuration. The following is a description of the thermistor:

GSFC PPL Number:	311P18
Description:	Thermistor. Insulated, Negative Temperature Coefficient
Resistance @ 25°C:	2252
Operating Range:	-55 to +70°C
Part Number:	311P18-02LXXX (See Catalog for details)
Manufacturer:	Yellow Springs Instrument

### 3.2.4 Speed Limiter

In order to limit maximum wheel power consumption and to limit rotor speed to safe values, the MDE incorporates redundant speed limiters.

The primary speed limiter operates from the tachometer information and limits rotor speed to a nominal value of 2500 rpm. The redundant speed limiter measures the back-EMF of the motor. Redundant speed limiter range is 3150-3900 rpm worst case, 3500 rpm nominal.

## 3.3 Structural/Mechanical Interface Characteristics

The RWA is essentially two separate units interconnected by a cable, thus the structural and mechanical interfaces can be treated separately for the RW and the RWE.

### 3.3.1 RW Structural/Mechanical Interface Description

The RW contains the flywheel, motor and suspension system. The outline drawing (D43758) is contained in Appendix B. The layout of the RW consists of a titanium flywheel suspended on precision angular contact ball bearings and driven by an ironless armature brushless DC motor. Hall sensors are integrated directly into the motor to provide commutation information as well as a high resolution tachometer signal. The aluminum housing consists of cylindrical and conical structural sections, and removable dome shaped access panels on the top and bottom to provide assembly access and to improve inspectability.

### 3.3.1 RW Structural/Mechanical Interface Description (Cont'd)

The RW mechanical interface to the spacecraft is by a mounting flange on the outer diameter of the RW housing. Sixteen thru holes are used to secure the flange to the spacecraft mounting surface. The surface flatness of the mounting surface on the RW is controlled to better than 0.0005 in/in<sup>2</sup>. The mounting interface on the spacecraft must be controlled to the same order of flatness, in order to prevent unacceptable deformations due to mounting.

The momentum vector alignment is controlled relative to the mounting surface. A single surface mirror is provided as an alignment tool. The alignment of the mirror is measured relative to the mounting surface.

For good assembly practice, it is recommended that the mounting screws or bolts be first snugged down finger tight, and then individually torqued in a star pattern.

### 3.3.2 RWE Structural/Mechanical Interface Description

The RWE is located in a separate box. The outline drawing (D44342) is contained in Appendix B. The RWE mechanical interface to the spacecraft is a rectangular surface with two mounting flanges. Three thru holes are used on each mounting flange to secure the flange to the spacecraft mounting surface. The surface flatness of the mounting surface on the RWE is controlled to better than 0.001 in/in<sup>2</sup>. The mounting interface on the spacecraft must be controlled to the same order of flatness, in order to prevent unacceptable deformations due to mounting, and maintain low contact resistance.

For good assembly practice, it is recommended that the mounting screws or bolts be first snugged down finger tight, and then individually torqued in a star pattern.

## 3.4 Thermal Interface Characteristics

The RWA is essentially two separate units interconnected by a cable, thus the thermal interfaces can be treated separately for the RW and the RWE.

### 3.4.1 RW Thermal Interface Characteristics

Although the thermal design of the RW does not require conduction of heat through the mounting surface, it is expected that a significant portion of heat rejection will be conducted. The baseplate has a controlled surface finish and flatness as shown on the outline drawing. The aluminum mating surface is protected by an electrically conductive chromate conversion coating per MIL-C-5541, Class 3.

The RW exterior is finished with black anodize per MIL-A-8625, which has a typical emissivity of 0.80. The RW operating temperature range is -30° to +50°. The maximum T/t is 0.5°C/min.

### **3.4.2 RWE Thermal Interface Characteristics**

The RWE thermal interface to the spacecraft is to conduct through the baseplate. In order to accommodate this, the baseplate has a controlled surface finish and flatness as shown on the outline drawing. The aluminum mating surface is protected by an electrically conductive chromate conversion coating per MIL-C-5541, Class 3.

The external mounting surfaces have an emissivity greater than 0.85. This is accomplished by the application of Chemglaze Z306 Black Polyurethane paint.

The RWE baseplate temperature range is -30 to +60°C. The maximum  $T/t$  is 0.5°C/min.

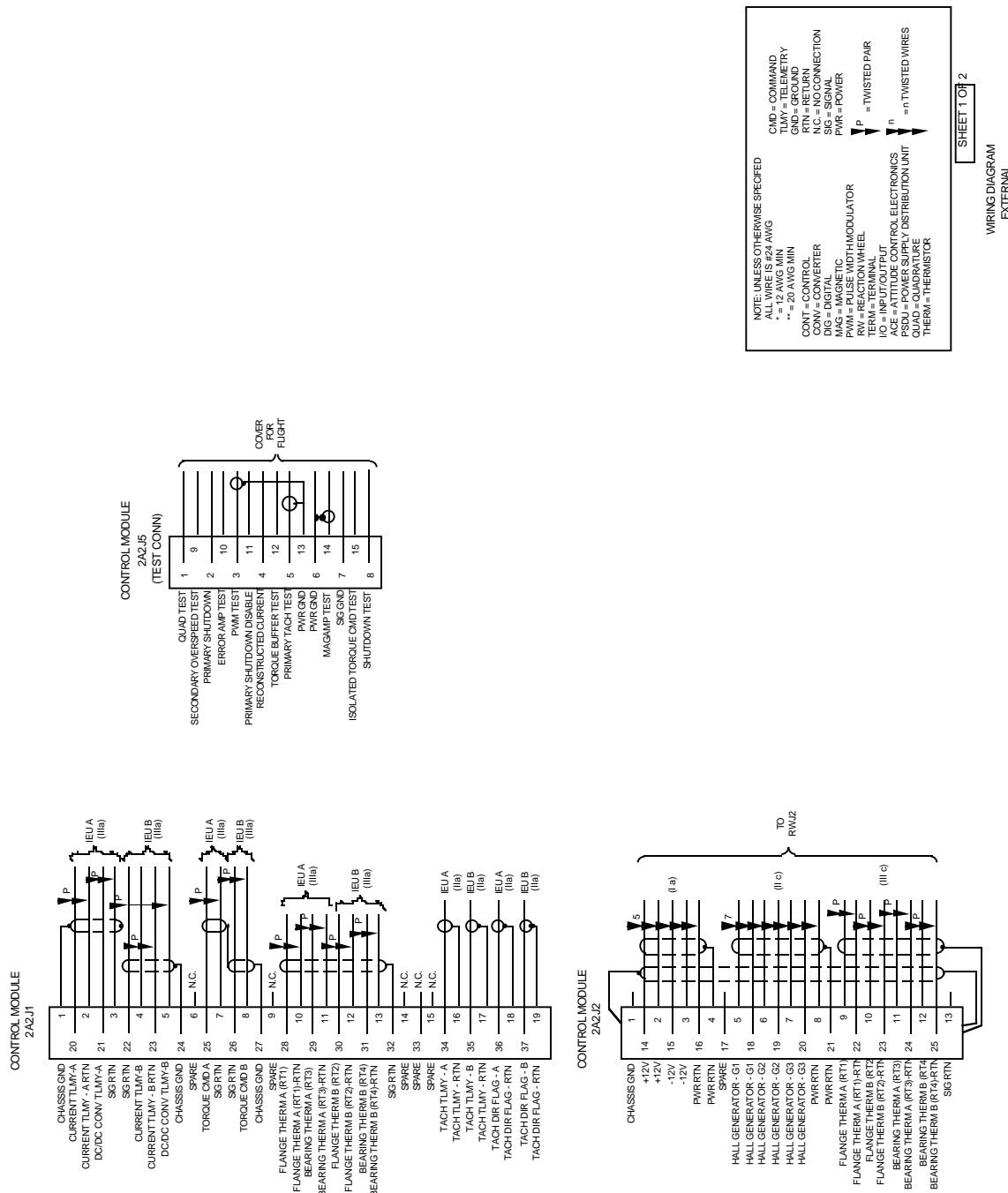
## **4.0 CONCLUSION**

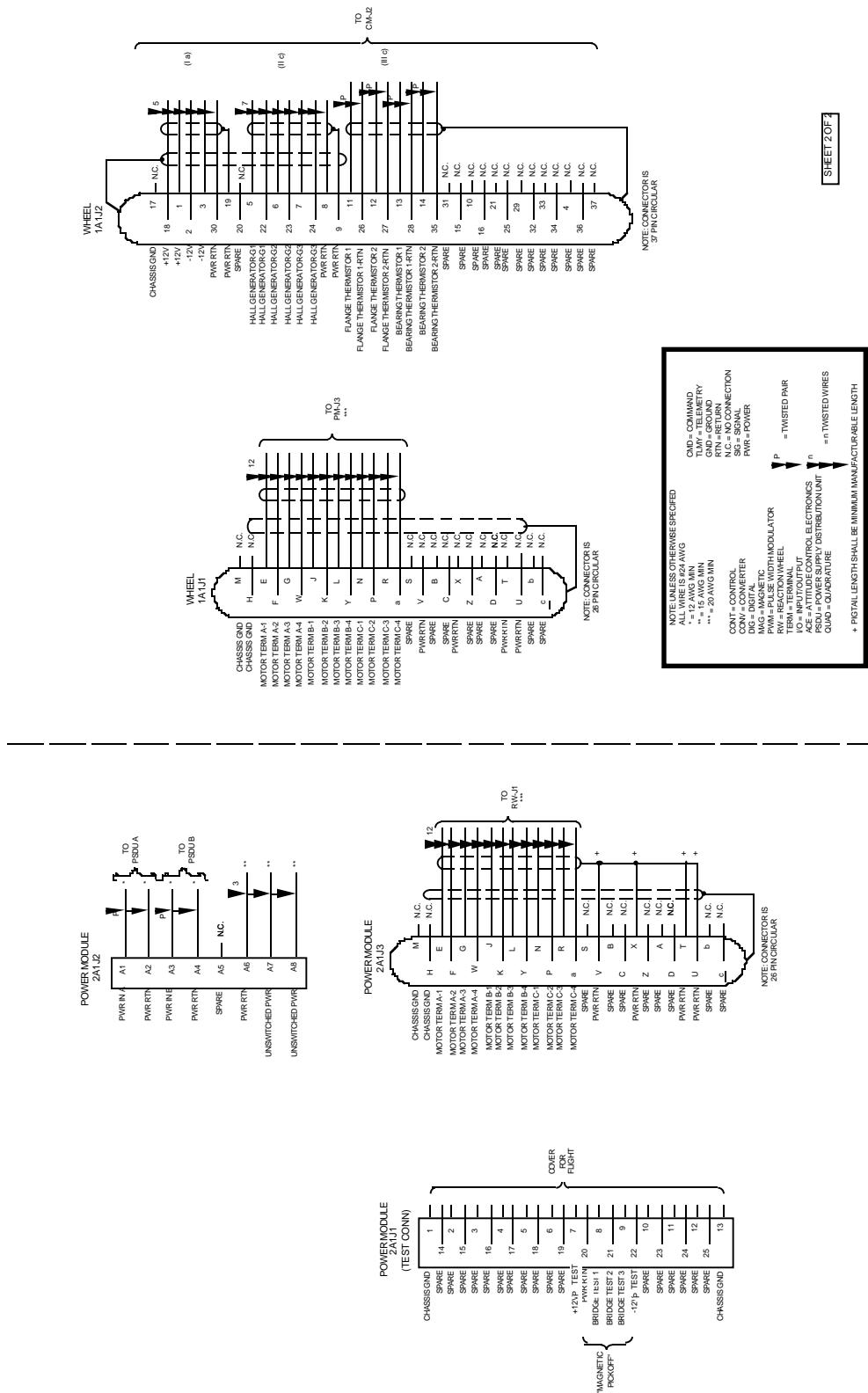
The electrical, structural, mechanical and thermal interfaces for the RW and RWE have been described in detail herein.

**Report 95158**  
**February 18, 2000**

## **APPENDIX A**

### **CONNECTOR SIGNAL DEFINITION (Interconnection Diagrams) (Dwg. No. D44346)**





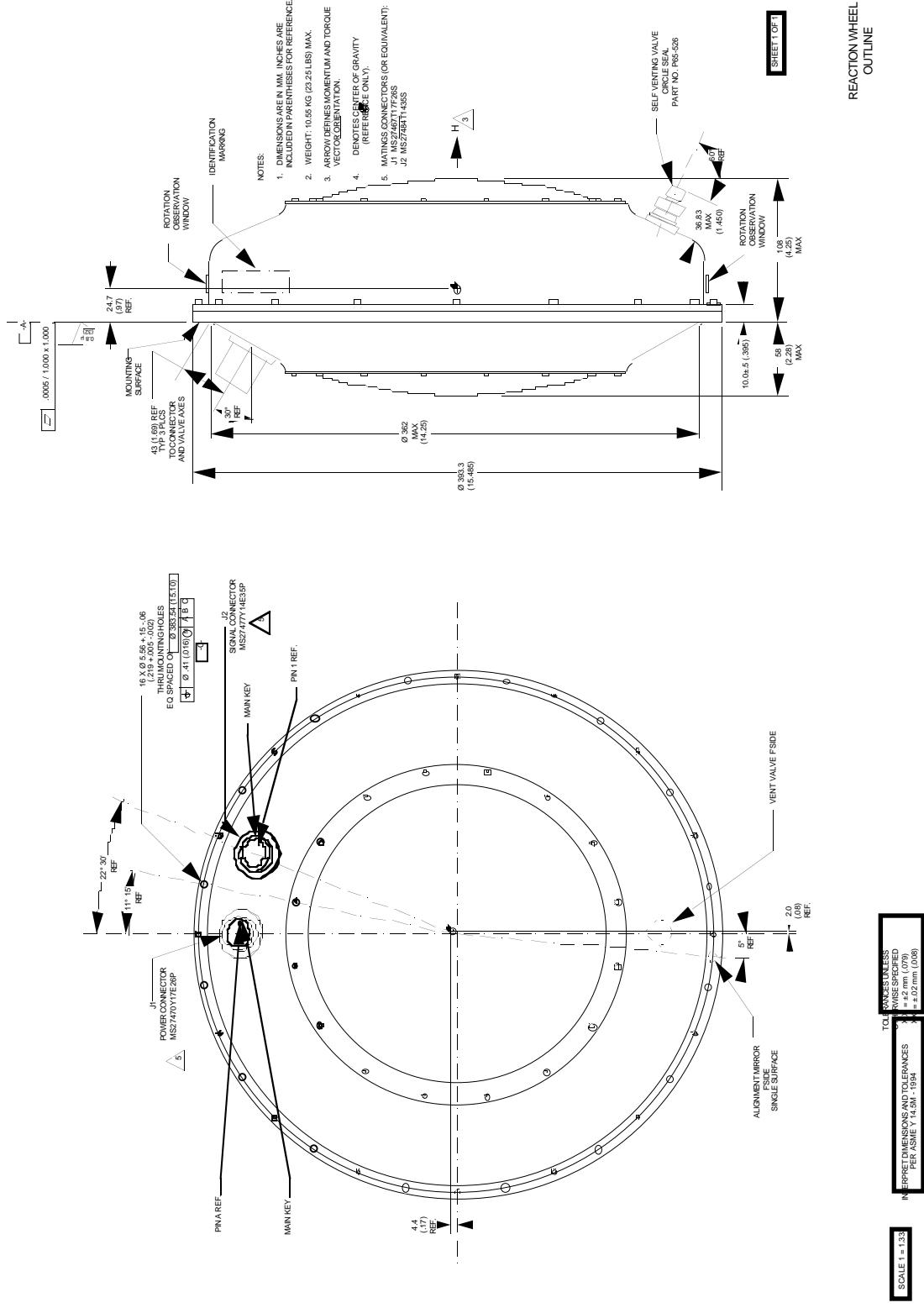
WIRING DIAGRAM  
EXTERNAL

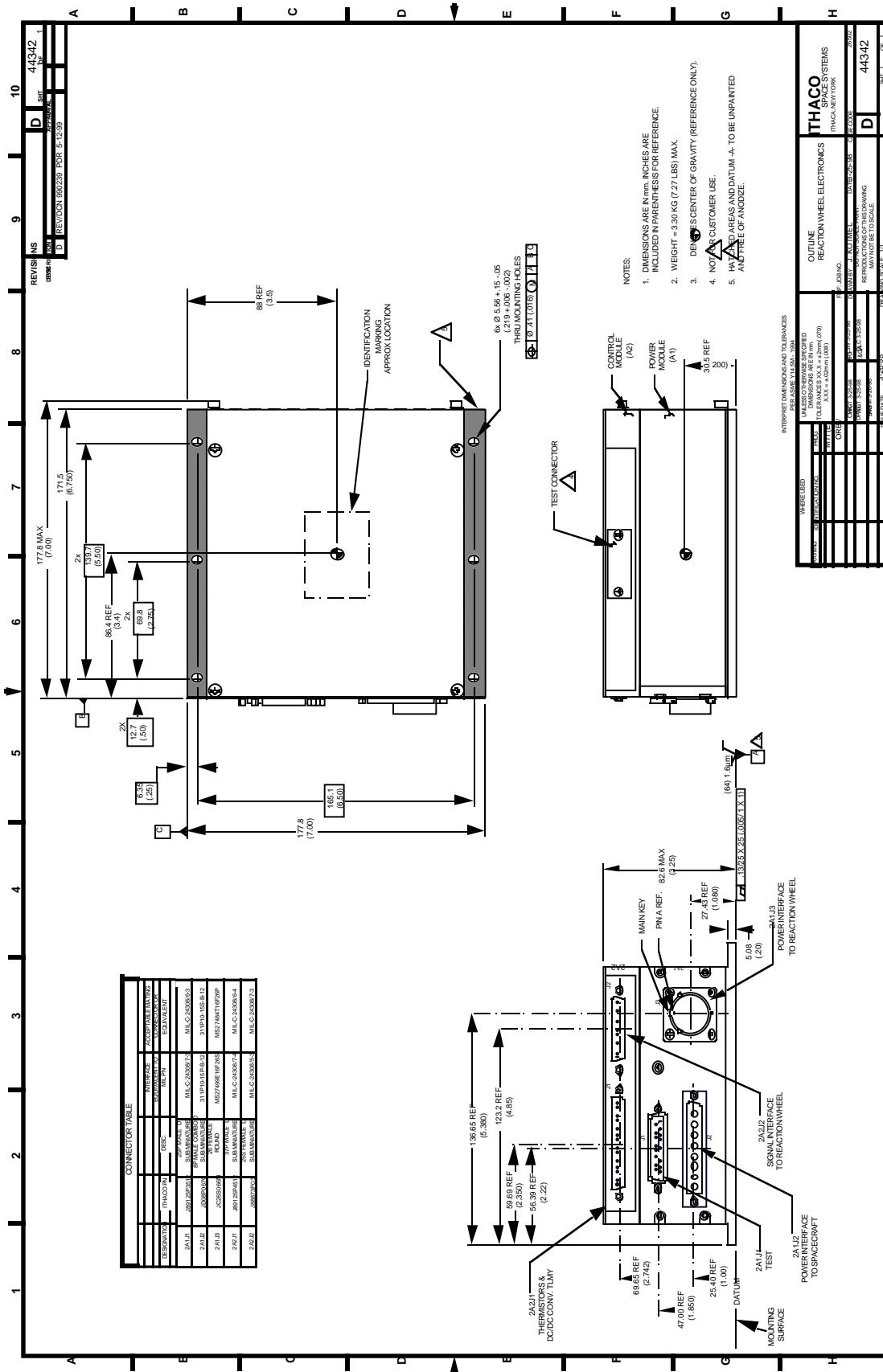
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**Report 95158**  
**February 18, 2000**

## **APPENDIX B**

### **REACTION WHEEL ASSEMBLY OUTLINE DRAWINGS (Dwg. Nos. D43758, D44342)**





## **APPENDIX C**

### **REACTION WHEEL ASSEMBLY BLOCK DIAGRAM (Dwg. No. D44345)**

